Power system value of smart versus dumb charging of EVs

Meibom, Peter; Kiviluoma, Juha

Publication date:
2011

Document Version
Publisher's PDF, also known as Version of record

Power system value of smart versus dumb charging of EVs

Peter Meibom, Risø DTU
Juha Kiviluoma, VTT, Finland

Modelling EVs in the power system

- Model runs with Wilmar and Balmorel
  - Investment decisions and costs from Balmorel (www.balmorel.com)
  - Operational costs from Wilmar (www.wilmar.risoe.dk)
  - Both have EVs included
  - Example case: Finland 2035
  - Time-scale is hourly, geographic resolution is regions or countries
  - Both models include an EV module (Wilmar module made by VTT)

- Note!
  - Grid impacts not included (distribution grids may be heavily impacted)

- *Kiviluoma, J., Meibom, P.,* Methodology for modelling plug-in electric vehicles in the power system and cost estimates for a system with either smart or dumb electric vehicles, Energy, epublished, DOI: 10.1016/j.energy.2010.12.053.

Generation investment model Balmorel

- Developed by Hans Ravn, RAM-løse edb
- Further development and usage: Risø DTU, EA Energianalyse, Cowi, Energinet.dk
- Balmorel is one of the few generation expansion models that handles wind power in hourly time scale
- The model optimises investments and operation of the energy system so that it can meet the loads from hour to hour over the whole year
  - Simplified to 26 weeks
  - Investment costs are annualised
  - Wind power is one of the investment options (at low price)
  - Includes CHP plants and heat boilers for district heating
  - No demand for reserves
  - Capacity adequacy requirement

Stochastic unit commitment and dispatch model Wilmar

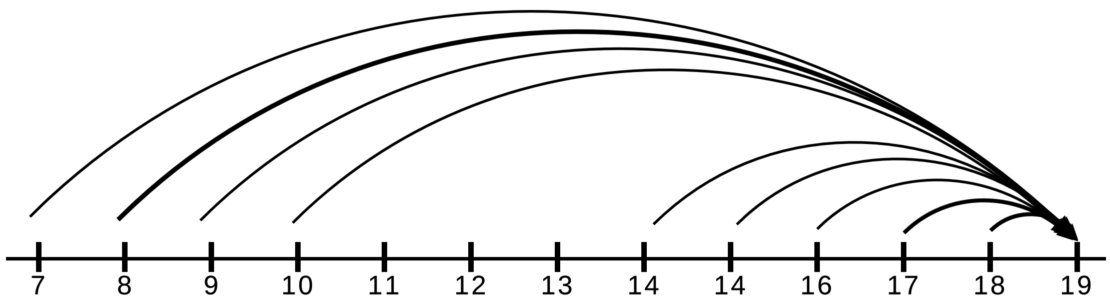
- Improve operational decisions in power systems (unit commitment and dispatch of units) by using not only:
  - The expected value of wind power and load forecasts
  - But also accuracy of forecast, i.e. the distribution of forecast errors
- Approach:
  - Hourly system-wide stochastic optimisation model with stochastic input parameters
  - Covering both day-ahead scheduling and rescheduling (up and down regulation) due to updated forecasts
  - Rolling planning with updated forecasts
  - Exogenously defined demand for positive spinning reserve
  - Endogenously defined demand for tertiary reserves (regulating power)

Dumb versus smart charging

- Dumb charging:
  - Vehicles start charging at maximum loading capacity as soon as plugged in and countinues until batteries are full
  - No provision of reserves and no V2G
  - EVs have similar effects as wind: net load variability increases
- Smart charging:
  - V2G possible
  - Charging/discharging planned day-ahead
  - Rescheduling of charging/discharging plans possible intra-day
  - EVs can provide spinning and tertiary reserves by reserving charging/discharging capacity
- Cases are extreme: all EVs are smart or all EVs are dumb charging

Modeling of vehicle behaviour

- Data from the Finnish National Transport Survey 2004-2005
- The share of arriving and departing vehicles for each hour
- Accounts for the variatioin in average distance travelled
- Separately for weekdays, Friday, Saturday, Sunday, official holidays, and days between a weekend and a holiday
- Weekly index to accommodate inter-annual variation
- Departure and arrival are linked



Modeling of EVs

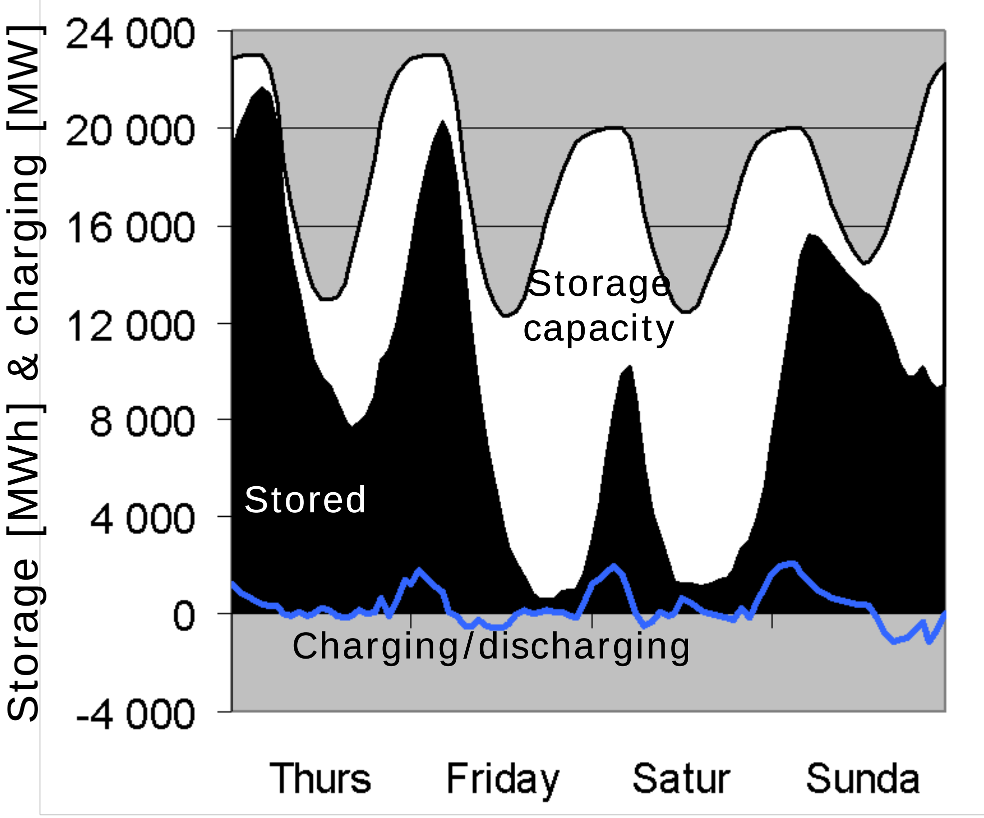
- EVs modeled as electricity storages not always connected to the power grid and while gone, spend some of their stored electricity
- Each vehicle type has its own general electricity storage pool in each model region
- Leaving vehicle takes required amount of electricity from the storage pool
- It also takes away the amount of storage capacity its battery has and gives it back upon arrival

Study setup

EVs

- ½ million full electric vehicles (FEVs), ½ million PHEVs
- 200 km driving range for FEVs
- 100 km driving range of PHEVs
- Plug-in pattern:
  - 98% at home
  - 20% at work
- Driving pattern:
  - On average 3 trips per day
  - Combined distance of 52 km
  - Charging opportunity every 39 km
- Usable storage size
  - Fluctuates
  - Around one hour of peak demand
  - EVs leaves grid with full batteries

Storage capacity and usage (model results)



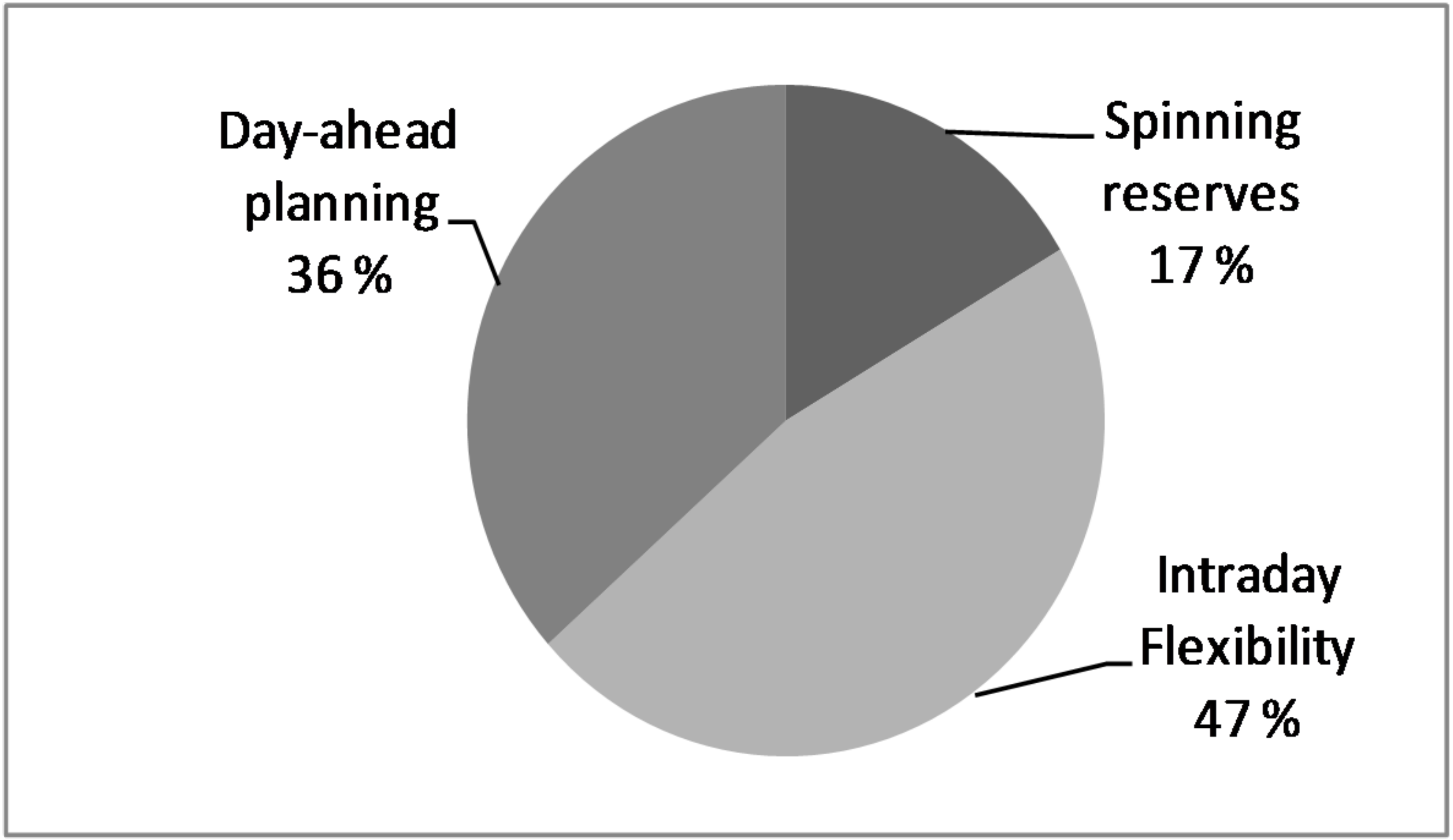
Capacity of New Power Plants in the Different Balmorel Scenarios

	MW of Electricity			
Power Plant Type	No EVs	Dumb	Smart	No 500
NatGas comb. cycle cond.	363	520	16	16
NatGas open cycle cond.	2861	3580	2519	3024
Nuclear	5312	5688	5312	5312
Wind	4705	5130	6122	6122
Forest residue CHP	1203	1206	1196	1192
Wood waste CHP	76	73	73	75

Calculating benefits of smart charging by comparing model runs

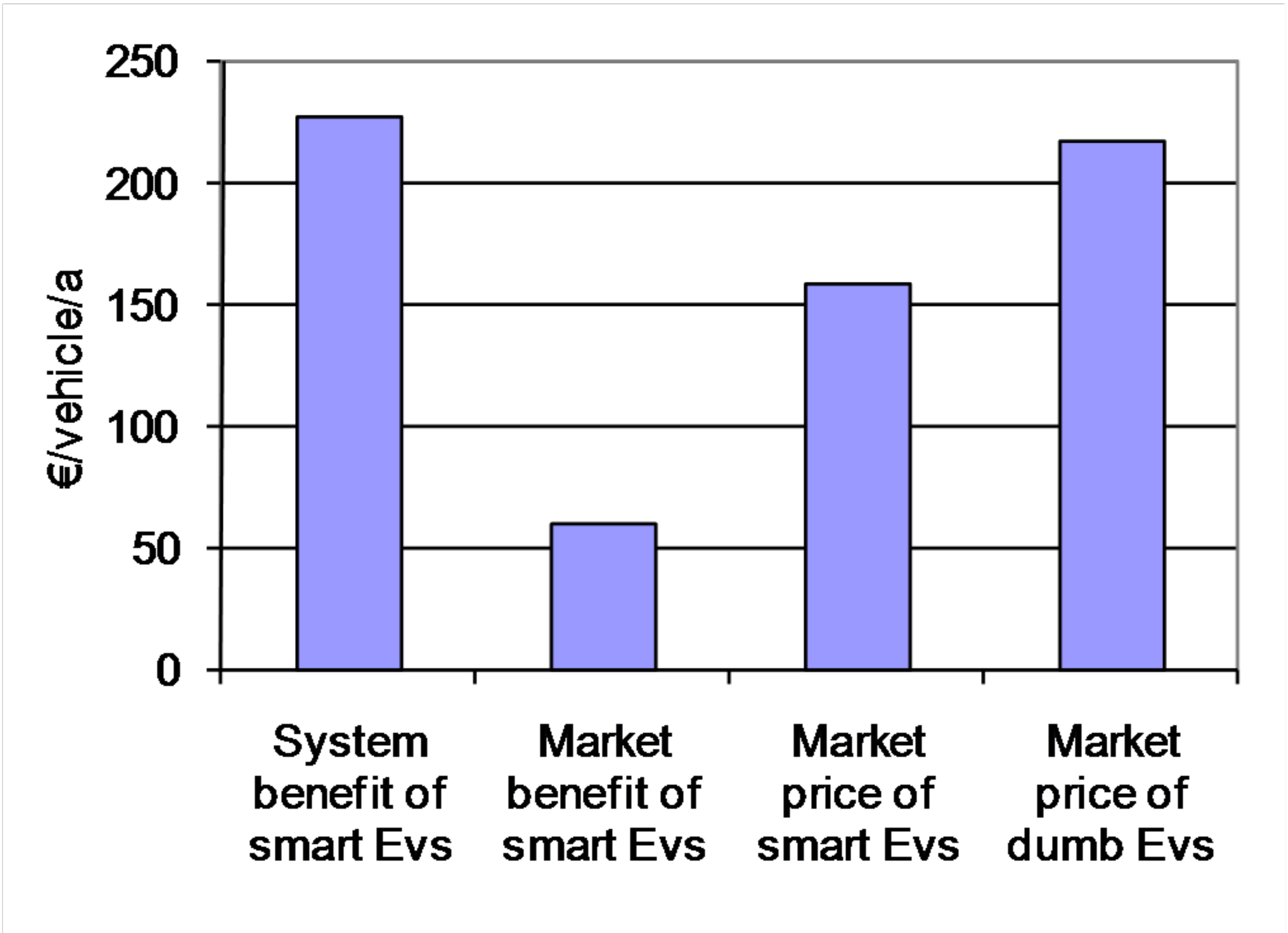
	Balmorel run	Wilmar run
Spinning reserve	Smart	Smart
	Smart	Smart no spin
Intra-day flexibility	Smart	Smart no spin
	No 500	Smart, no spin, no intra-day flexibility
Day-ahead planning	No 500	Smart, no spin, no intra-day flexibility
	Dumb	Dumb

BENEFITS OF SMART CHARGING



Total 227 €/vehicle/year

SYSTEM VS. MARKET BENEFITS



VEHICLE-TO-GRID

Scenario	Cost over Base (€/vehicle/year)
No V2G allowed	53
V2G half of the vehicles	6,7

Conclusions

- Smart charging allows for higher amount of wind power
- Timing of charging constitutes main part of benefit with V2G less important
- Benefit for vehicle users of smart charging only 25% of socio-economic benefit
- Benefit of V2G mostly related to provision of spinning reserves
- 87% of V2G benefit can be provided by equipping half of the vehicles with V2G